Surface Micro-Hardness and Wear Resistance of a Self-Adhesive Flowable Composite in Comparison to Conventional Flowable Composites

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Article Info	A B S T R A C T
Article type: Original Article	**Objectives:** The durability of composite restorations is directly affected by the mechanical properties of the composite. The aim of this study was to evaluate the hardness and wear resistance of self-adhesive flowable composite (SAF) in comparison with conventional flowable composites.
	Materials and Methods: In this in vitro study, 50 composite specimens were prepared in brass molds with 10mm ×10mm ×2mm and divided into five groups (n=10). Specimens included three conventional flowable composites (Grandio flow, Filtek flow and Admira fusion flow), one self-adhering flowable composite (SAF, Vertise flow) and a microhybrid composite (filtek z250). After polishing, the micro-hardness of the specimens was measured in a Vickers hardness device, and the specimens were then subjected to 5000, 10000, 20000, 40000, 80000 and 120000 wear cycles in a wear tester. One-way ANOVA/Games-Howell, Kruskal Wallis, and Friedman tests were used for statistical analysis. The significance level was set at $P<0.05$.
* Corresponding author: Dental Materials Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, IR Iran Email: dr.b.esmaeili@gmail.com	**Results:** The surface micro-hardness of the SAF was significantly lower than that of the microhybrid composite ($P=0.01$). There was no significant difference between the surface hardness of the different tested flowable composites ($P>0.05$). Also, the wear resistance of the studied composites was not significantly different in various cycles ($P>0.05$). **Conclusion:** Based on our results, SAF would not be an ideal substitute for conventional flowable composites in high-stress areas. **Keywords:** Dental Restoration Wear; Hardness; Composite Resins; Flowable Hybrid Composite

INTRODUCTION

In dentistry, there is currently a growing interest in developing materials that are more efficient, with fewer and simpler clinical steps. Flowable composites were first introduced in 1955 and have since become widely used due to their low viscosity, ease of use, and injectability. More recently, self-adhesive flowable composites (SAFs) have been introduced to the market. These materials do not require an adhesive and the manufacturer claims that they can attach to teeth through chemical and micromechanical interactions. This is achieved through the use of GPDM (glycero-phosphate dimethacrylate), an acid monomer, in the composition of the

SAF. This compound can bind to hydroxyapatite via the phosphate group, both in enamel and dentin [1]. However, due to the novelty of these materials, further studies are needed to fully understand their properties.

One of the most important factors that influences the physical and mechanical properties of composites is the degree of conversion. A lower degree of conversion results in restorations with lower mechanical properties, color changes, and greater degradation [2]. There are several techniques for evaluating the polymerization of composites, which can be divided into two main groups: direct and indirect methods. Direct methods, such as Fourier Transform Infrared Spectroscopy (FTIR), are expensive, complex, and time-consuming. In FTIR spectroscopy, the absorption of infrared radiation by the double bond of carbon is evaluated before and after curing, based on an accurate formula. In contrast, indirect methods, such as hardness and scraping tests, are inexpensive and easy to perform.

Surface hardness is defined as the penetration of an indenter into the material [3]. Hashemikamangar et al. [4] compared the surface microhardness of a SAF with that of conventional composite resins. The results showed that the SAF had lower hardness than the conventional composites, and aging significantly reduced the hardness of the composites. However, there is limited information available on the hardness of SAF

Also, one of the optimal properties for restorative materials is wear resistance. Ideal dental restorations should have tooth-like wear resistance [5]. Wear is defined as the loss of material because of mechanical interaction between a solid surface and wear particles harder than the surface under wear. Clinically, restorative wear can occur because of functional and centric contacts, food properties, interproximal contact areas, and brushing [6]. The properties of the composite that affect wear rate include content and size of filler. By reducing the size of the filler, the rate of organic matrix between the particles is reduced so that it will not be removed during the wear process [7]. In their study, Sumino et

al [8]. showed that flowable composites have higher wear resistance than conventional nanohybrid composites. Also, Asefi et al [7] compared the wear resistance of two flowable resin composites with posterior resin composites. It was revealed that flowable composite had the same wear resistance as Nano, Microfilled and Microhibrid resin composites. Due to the limited information about SAF, this study aimed to investigate the hardness and wear resistance of SAF compared to conventional flowable composites.

MATERIALS AND METHODS
In this in vitro study (Ethics Code: IR.MUBABOL.REC.1399.318), four flowable composites (three conventional flowable composites and one SAF) and one microhybrid composite were used. The chemical composition of these materials is presented in Table 1.

Preparation of Specimens
Fifty composite specimens were prepared in brass molds (10mm×10mm×2mm), and divided into five groups of 10 specimens each. First the mold was filled with composite and then a mylar strip and a glass slap were pressed on it with finger pressure. The specimens were exposed to light using an LED light curing device (Valo, ultradent, USA) with an intensity of $1000 \, mW/cm^2$ at 385-515nm for 20 seconds. The head of the exposure device was adjusted to make contact with the glass slab, and the light intensity was regularly checked after every five exposures using a radiometer (Optilux, Kerr, USA). After curing, the mylar strip and glass plate were removed, and the specimens were slowly taken out from the mold. The surface of the specimen was then polished with 400 to 2000 grit sandpaper (Softflex Matador, Wasserfest, Germany) to remove excess resin. Finally, the specimens were subjected to the following tests.

Micro-Hardness Test
The specimen hardness was measured using a Vickers hardness device (MH1 Koopa Pazhoohesh, Tehran, Iran) with a load of 100g applied for 20 seconds. Surface hardness was measured at three points on each specimen, and the mean hardness was considered the specimen hardness.

Table 1. Composition of the materials used in the study

Composites	Type	Composition	Manufacturer
Vertise flow	Light cured, self-adhering flowable composite	Glycerol phosphate dimethacrylate, prepolymerized filler, barium glass filler, nano-sized colloidal silica, nano-sized ytterbium fluoride	Kerr Corp., USA
Grandio flow	Flowable universal nano-hybrid composite	80 wt% Inorganic filler, 20 wt% BIS GMA*, TEGDMA**, HEDMA#	Voco, Cuxhaven, Germany
Filtek flow	Flowable, light-curing nano composite	Bis-GMA, TEGDMA and Bis-EMA@, silica (75nm) and zirconia (5-10 nm) nanofillers, approximately 65% wt filler load	3M ESPE Dental products St. Paul, Minnesota USA
Admira fusion flow	Flowable light-curing nano-hybrid ORMOCER	Fillers and matrix are based purely on silicon oxide	Voco, Cuxhaven, Germany
Filtek Z250	Universal hybrid composite	UDMA$, BIS-EMA and BIS-GMA 66% in volume zirconium glass and colloidal silica	3M ESPE Dental products St. Paul, Minnesota USA

*BIS-GMA: bisphenol-A diglycidyl ether dimethacrylate; **TEGDMA: Triethyleneglycol dimethacrylate; #HEDMA: hydroethyl dimethacrylate; @BIS-EMA: bisphenol A polyethyleneglycol diether dimethacrylate; $UDMA: urethane dimethacrylate

Table 2. Wear rate and surface micro-hardness (N/mm^2) ± SD in the different composites

	Filtek Z250	Vertise flow	Admira fusion flow	Grandio flow	Filtek flow	P
Hardness	74.95±34.13[a]	48.39±18.02[b]	57.05±13.73[ab]	61.07±10.42[a]	64.85±7.46[a]	<0.001
Wear rate	2.51±5.42[a]	0.50±1.16[a]	4.50±3.67[b]	3.31±3.58[b]	2.67±2.67[b]	0.01

Different letters in each row indicate a significant difference

Table 3. Mean wear ($\times10^{-4}$g) ± standard error of the composites in six different cycles

Composites	5000	10000	20000	40000	80000	120000	P
Filtek Z250	9.8±3.47[a]	10.6±3.32[ab]	11.3±3.35[ab]	12±3.40[abc]	12.8±3.44[b]	13.3±2.71[c]	0.019
Vertise flow	8.1±1.72	8.80±1.95	9.8±2.11	9.84±2.94	11.9±2.45	15.4±6.62	0.27
Admira fusion flow	5.4±1.34[a]	7.1±1.42[a]	7.90±1.52[a]	9.5±1.64[a]	12.4±1.61[b]	17.5±2.13[b]	<0.001
Grandio flow	10.7±6.36[a]	15.5±8.05[b]	16±7.97[b]	16.7±.12[b]	18.4±8.29[b]	21.1±8.04[c]	0.001
Filtek flow	5.9±2.17[a]	10.2±2.75[a]	12.3±3.93[a]	14.8±3.96[b]	15.5±3.87[b]	16.6±4.37[b]	0.01
P	0.27	0.92	0.89	0.97	0.62	0.36	

Different letters in each row indicate a significant difference at the level of α=0.01

Wear Test

Before wear, each specimen was placed on a special plate with a paper dryer for 10 minutes at 37 degrees to ensure even dehydration. Then, it was weighed using an electronic scale (Start Orius, Germany) with an accuracy of 0.1 mg and recorded in the table. The wear test was performed using a wear tester (Pajoohesh Dandanpezeshki, Babol, Iran). The wear tip size and load used during the wear process were 1.98 mm² and 6 kg, respectively. After placing the specimens in the wear machine, they were subjected to wear cycles of 5000, 10000, 20000, 40000, 80000, and 120000, respectively, and their weight was measured after each wear cycle. It should be noted that 100000 cycles for the composite is equivalent to 3.6 months of use in the clinic [9]. The difference between the masses of the specimens before and after wear was calculated as the lost wear volume.

Statistical analysis

The mean hardness and wear rate were calculated for all groups and the data were analyzed. Then, the hardness data were analyzed using One-way ANOVA and Games-Howell tests, and the wear data were analyzed using Kruskal Wallis and Friedman tests. Its pairwise comparisons were analyzed using Adjusted Bonferroni test. Also, the wear rate was calculated and examined using Kruskal Wallis and Adjusted Bonferroni tests. Significance level was considered at $P < 0.05$.

RESULTS

Table 2 displays the mean surface hardness of the composites individually. Z250 composite had the highest hardness with a mean of 74.95 N/mm², while Vertise flow composite had the lowest with a mean of 48.39 N/mm². The mean hardness of the composites differed significantly ($P < 0.001$). Table 3 and Figure 1 present the mean wear of the composites over 5000, 10000, 20000, 40000, 80000, and 120000 cycles. The mean wear did not show any significant difference among the five composites during these cycles ($P=0.28$). However, the wear rate showed significant differences among the composites ($P=0.01$). Admira fusion composite exhibited the highest mean wear rate, as indicated in Table 4 and Figure 2.
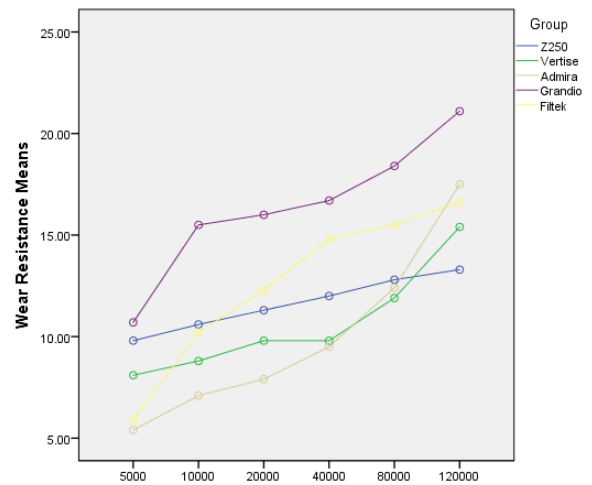

Fig 1. Mean wear ($\times 10^{-4}$g) of the composites during the six studied wear cycles
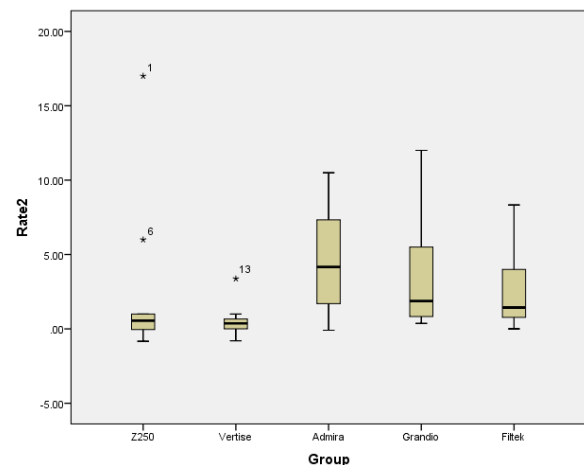

Fig 2. Wear rate for the studied composites

DISCUSSION

The present study examined the surface hardness of one SAF, one microhybrid composite and three conventional flowable composites. Our results revealed that the hardness of the SAF composite was signify-cantly lower than that of the microhybrid and flowable composites. This finding is consistent with a previous study conducted by Hashemikamangar et al [4]. The hardness of composite resins is largely dependent on the material and is related to the characteristics and quality of the matrix as well as the filler content. Increasing the filler content of a composite improves its mechanical properties [2,10-12].

In our study, Filtek Z250 had the highest filler volume (66%) and Vertise flow had the

lowest filler volume (44%), which is consistent with the observed surface hardness results. However, the flowable composites with different filler volumes showed almost the same hardness in our study, in agreement with various previous studies [13,14]. In contrast, Hashemikamangar et al [4] found different hardness values for Premise flowable and Filtek Z250 composites with different filler volumes. They suggested that the type of filler material might be the reason for the higher hardness of the Filtek Z250, as harder filler particles in the composite lead to a higher surface hardness [15-18]. The poor behavior of the SAF composite, in addition to the low amount of filler, may be attributed to the presence of pre-polymerized fillers. These particles were initially added to composites to reduce the shrinkage of polymerization, but they do not bind to the matrix with silanization, so they are easily separated under stress [4,19,20].

Additionally, the chemical composition of the matrix is another crucial factor that affects the hardness of composites. Various monomers with different properties have been utilized in the chemical structure of composites [21-23]. Composites with UDMA monomer as their main matrix are generally harder than composites containing Bis-GMA and Bis-EMA [11]. In our study, Filtek Z250 composite, which contains UDMA monomer, had the highest hardness, while Vertise flow matrix, which contains Bis-GMA, Bis-EMA, BISPAD, and GPDM, had the lowest hardness.

In addition to hardness, wear resistance is another important factor that affects the durability of dental restorations. In our study, we investigated the wear of five different composites in six different cycles of 5000, 10000, 20000, 40000, 80000, and 120000. Our results showed that there was no significant difference in wear among the five composites in all six cycles. Asefi et al [7] also found similar results in their study where they showed that flowable and other types of composites had similar wear resistance. Composite wear is a complex process that is influenced by various internal and external factors. One of the key factors is the properties

of the filler such as its size, hardness, and volume. As the volume of filler increases and its size decreases, the wear resistance of the material improves [24]. Chimello et al [6] reported similar findings where they showed that despite having a filler volume of 30-50%, flowable composites have good wear resistance due to the presence of small fillers and inter-particle spaces that protect the matrix. On the other hand, Sumino et al [8] showed that flowable composites have higher wear resistance than conventional nano-hybrid composites. The higher wear of the nanohybrid composite was attributed to the presence of larger pre-polymerized filler particles in its content. These particles can be easily removed from the matrix due to the lack of binding, reducing the overall filler content. Consequently, the existence of pre-polymerized filler particles in composites can lower their mechanical properties [19].

Despite the similar wear of composites in different wear cycles, the wear rate of the composites varied significantly. For instance, Admira Fusion Flowable composite had the lowest wear rate initially, but eventually, it exhibited the highest wear rate among the composites. Admira Fusion Flowable composite is a Nano-ormocer (organically modified ceramic) composed of a filler and matrix based on silicon oxide. Some literature suggests that the properties of Ormocers are lower than those of hybrid composites, with very low wear resistance [25,26]. However, information on this material is limited, and further studies are needed in this regard. Although hardness and wear are critical properties for the clinical service of restorative materials, other physical and mechanical properties should also be considered. This in vitro study does not eliminate the need for clinical studies. It would be better to conduct studies under similar clinical conditions, such as force, saliva, and aging.

CONCLUSION

The study yielded several findings on the different composites tested. Firstly, the hardness of the SAF was significantly lower

compared to the microhybrid composite. Secondly, the hardness of flowable composites were similar to one another. Thirdly, there was no significant difference in the mean wear among the five composites in the six wear cycles. Finally, the mean wear rate was significantly different among the different types of composites, suggesting that some types of composites are more prone to wear than others.

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CONFLICT OF INTEREST STATEMENT

None declared.

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